

TITLE OF THE INVENTION  
BALL BEARING

BACKGROUND OF THE INVENTION

5 [Field of the invention]

The present invention relates to a ball bearing, and more particularly to a ball bearing in which an annular cage having cylindrical pockets radially passing through the annular cage is guided by one of bearing rings.

10 [Description of the related art]

In a ball bearing, in general, an annular cage having pockets in several positions in a circumferential direction is incorporated between a pair of bearing rings disposed inside and outside in a radial direction. A ball is housed in each pocket of the annular cage.

15 There are annular cages of a type guided by balls and of a type guided by an inner ring as an inside bearing ring or an outer ring as an outside bearing ring.

20 Normally, the annular cage of the latter type guided by the outer ring is selected for use for high-speed rotation.

The present inventor examined states of vibration and a temperature rise of the ball bearing of the type in which the annular cage is guided by one of the bearing rings. As a result, the vibration and temperature rise were liable to be generated when a radial clearance (guide clearance) of the annular cage with respect to the one bearing ring was set to be larger than an axial clearance or a circumferential clearance (pocket clearance) of a pocket inner wall face with respect to the ball.

In other words, as a result of eccentric rotation

of the annular cage due to centrifugal force in the high-speed rotation, the inner wall face of the pocket interferes with the ball from the radial or circumferential direction. Therefore, each ball advances and lags. As a result variations in a pitch error of the balls increase to thereby cause a minute slip of the ball, which leads to generation of the above-described vibration and temperature rise.

#### SUMMARY OF THE INVENTION

In a ball bearing of the present invention, in summary, an annular cage with cylindrical pockets along an radial direction and formed through the annular cage in several positions on a circumference is incorporated between a pair of bearing rings disposed inside and outside in the radial direction, a ball is housed in each pocket, and the annular cage is guided by one of the bearing rings. A relationship between  $\alpha$  and  $\beta$  is set at  $\alpha \leq \beta$  if a guide clearance of the annular cage with respect to the one bearing ring is  $\alpha$  and a pocket clearance of a pocket inner wall face with respect to the ball is  $\beta$ . According to such a ball bearing, the annular cage is guided by the one bearing ring even if the annular cage rotates in an eccentric manner in high-speed rotation. Thus, the inner wall face of the pocket hardly interferes with the ball especially when the annular cage is displaced in the radial direction. As a result, behavior of the annular cage becomes liable to be stable. Each ball becomes less liable to advance and lag.

Especially, in the ball bearing of the invention, a relationship between  $\alpha$  and  $\beta$  is set at  $x+y < \alpha \leq \beta+x$  if an expansion amount of the annular cage in the radial direction due to rotational centrifugal force is  $x$  and

an expansion amount of the annular cage in the radial direction due to thermal expansion is  $y$ . By such a setting, the expansion amount  $x$  of the annular cage in the radial direction due to rotational centrifugal force and the expansion amount  $y$  of the annular cage in the radial direction due to thermal expansion are added and the invention becomes more effective in terms of practical use.

In the ball bearing of the invention, it is preferable that races with sectional shapes corresponding to parts of an arc are provided to the inner and outer bearing rings. The balls are in contact with the races in both of the bearing rings with predetermined contact angles. By such contact, the invention is formed into an angular contact ball bearing in which a preload is applied to make an internal clearance substantially zero as a type of the ball bearing. Therefore, advance and lag of the ball is suppressed. As a result, the invention is more effective to prevent interference between the balls and the annular cage.

#### BRIEF DESCRIPTION OF THE DRAWINGS

These and other objects as well as advantages of the invention will become clear by the following description of preferred embodiments of the invention with reference to the accompanying drawings, wherein:

FIG. 1 is a sectional view of an angular contact ball bearing according to a preferred embodiment of the present invention;

FIG. 2 is a view taken along a line (2)-(2) in FIG. 1;

FIG. 3 is a perspective view of an annular cage with a portion cut out;

FIGS. 4A to 4D are drawings each showing a relationship between a guide clearance  $\alpha$  and a pocket clearance  $\beta$ ;

5 FIG. 5 is a diagrammatic illustration for explaining circular portions respectively shown in FIGS. 4A to 4D;

10 FIG. 6 is a graph showing a maximum amount of displacement of the annular cage when the guide clearance  $\alpha$  is constant and the pocket clearance is a parameter; and

FIG. 7 is a sectional view of an angular contact ball bearing according to another preferred embodiment of the invention.

15 DETAILED DESCRIPTION OF PREFERRED EMBODIMENTS

20 A ball bearing according to preferred embodiments of the present invention will be described in detail by reference to FIGS. 1 to 6. This ball bearing can be applied not only to an angular contact ball bearing but also to other types of ball bearings.

The angular contact ball bearing 1 includes an inner ring 2, an outer ring 3, a plurality of balls 4, and an annular cage 5.

25 The inner ring 2 and the outer ring 3 form a pair of bearing rings disposed to face each other inside and outside in a radial direction.

30 A race 6 is formed in an axial intermediate position of an outer peripheral face of the inner ring 2. A sectional shape of the race 6 is a shape corresponding to a part of an arc. A counter bore with a diameter gradually reducing from the race 6 toward an axial end side is formed at axial one end portion on an outer peripheral face of the inner ring 2.

A race 7 is formed in an axial intermediate position of an inner peripheral face of the outer ring 3. A sectional shape of the race 7 is a deep groove shape corresponding to a part of an arc.

5 A pre-load is applied to the balls 4 such that the balls 4 are brought into contact with the respective races 6 and 7 of the respective inner and outer rings 2 and 3 at predetermined contact angles.

10 The annular cage 5 is disposed in an annular space between the inner ring 2 and the outer ring 3 where the inner and outer rings 2 and 3 face each other. The outside surface of the annular cage 5 is disposed close to the inner peripheral face of the outer ring 3 such that the annular cage 5 rotates along the inner  
15 peripheral face of the outer ring 3, which is referred to as outer ring guide.

A pocket 8 for housing each of a plurality of balls 4 is formed to radially pass through each of several positions of a circumference of the annular cage 5. The  
20 annular cage 5 is of a so-called machined type.

Each pocket 8 in the annular cage 5 is formed into a cylindrical shape along a radial direction. In this case, the annular cage 5 may be of a type called a pin type in which two annular members facing each other in  
25 an axial direction are coupled by a rivet.

In such an angular contact ball bearing 1, the outer ring 3 is fixed so as not to rotate, the inner ring 2 is rotatable, and the annular cage 5 is guided by the outer ring 3.

30 In this angular contact ball bearing 1, an internal clearance is set at zero by applying the pre-load in a state in which the bearing 1 is incorporated into a place where the bearing 1 is used. Here, the internal

clearance refers to a distance by which the one bearing ring can be moved in the radial or axial direction with respect to the other bearing ring in the angular contact ball bearing before mounting. The distance in the radial direction is referred to as a radial clearance and the distance in the axial direction is referred to as an axial clearance.

In the angular contact ball bearing 1 having the above structure, if a radial clearance (guide clearance) of the annular cage 5 with respect to the outer ring 3 is  $\alpha$  and an axial clearance or a circumferential clearance (pocket clearance) of the pocket 8 of the annular cage 5 with respect to the ball 4 is  $\beta$ , a relationship between the guide clearance  $\alpha$  and the pocket clearance  $\beta$  is set to be the following relational expression (1).

$$\alpha \leq \beta \quad \dots (1)$$

The guide clearance  $\alpha$  is a clearance in a state in which the annular cage 5 is put aside in the radial direction and brought into contact with the outer ring 3 and the clearance  $\alpha$  is expressed by the following expression (2).

$$\alpha = \alpha_1 + \alpha_2 \quad \dots (2)$$

, where  $\alpha_1$  and  $\alpha_2$  are respective guide clearances between an outer peripheral face of the annular cage 5 and the inner peripheral face of the outer ring 3 on one side and the other side of the annular cage 5 in the diameter direction of the annular cage 5. For example, when  $\alpha_1$  is the maximum value,  $\alpha_1 = \alpha$  and  $\alpha_2 = 0$ . When  $\alpha_2$  is the maximum value,  $\alpha_2 = \alpha$  and  $\alpha_1 = 0$ .

The pocket clearance  $\beta$  is a clearance in a state in which the annular cage 5 is put aside in the axial direction and brought into contact with the balls 4 and

the clearance  $\beta$  is expressed by the following expression (3).

$$\beta = \beta_1 + \beta_2 \quad \dots (3)$$

, where  $\beta_1$  and  $\beta_2$  are respective pocket clearances between wall faces of the pocket 8 in the annular cage 5 and the ball 4 on one side and the other side of the ball 4 in the axial direction of the annular cage 5. For example, when  $\beta_1$  is the maximum value,  $\beta_1 = \beta$  and  $\beta_2 = 0$ . When  $\beta_2$  is the maximum value,  $\beta_2 = \beta$  and  $\beta_1 = 0$ .

The above relational expression (1) between the guide clearance  $\alpha$  and the pocket clearance  $\beta$  was found from simulations performed by the present inventor. Description will be presented below by reference to FIGS. 4A to 4D.

FIGS. 4A to 4D respectively show a relationship between an eccentricity tolerance A of the annular cage 5 determined by the guide clearance  $\alpha$  and a rattling tolerance B of the annular cage 5 determined by the pocket clearance  $\beta$  when the relationship between the guide clearance  $\alpha$  and the pocket clearance  $\beta$  is  $\alpha > \beta$ ,  $\alpha = \beta$ , and  $\alpha < \beta$ .

Because it is preferable that the pocket clearance  $\beta$  is set at a dimension determined empirically, the guide clearance  $\alpha$  is used as a parameter. The number of the balls 4 to be used is 8, for example. As shown in the drawings, the eccentricity tolerance A forms a circle and the rattling tolerance B forms a polygon according to the number of balls 4 to be used and forms an octagon according to the number, 8, of the balls 4 to be used in the embodiment. A relationship between the number Z of the balls to be used and the number n of angles of the polygon of the rattling tolerance B is expressed by the following expressions (4) and (5).

$$n=Z \quad \dots (4)$$

, where Z is an even number.

$$n=2Z \quad \dots (5)$$

, where Z is an odd number.

5 The eccentricity tolerance A is a range in which the annular cage 5 can rotate in an eccentric manner between the inner ring 2 and the outer ring 3. Existence of the balls 4 is ignored such that movement of the annular cage 5 is not restricted by the balls 4. The  
10 eccentricity tolerance A will be described by reference to FIG. 5. FIG. 5 shows a state in which the annular cage 5 is put aside in the radial direction and brought into contact with the outer ring 3. In FIG. 5, a reference numeral P1 designates a geometrical center of the inner ring 2 and the outer ring 3. In this case,  
15 the inner ring 2 and the outer ring 3 are incorporated such that the centers of them are aligned with each other on P1. The center P1 is defined as a point of origin of a rectangular two-dimensional X-Y coordinate system. A reference numeral P2 designates a geometrical center of the annular cage 5, a reference character e designates an eccentricity of a center P2 of the annular cage 5 with respect to the center P1, and a reference character R designates a revolution locus of the center P2 of the annular cage 5. A diameter D of the revolution locus R corresponds to the guide clearance  $\alpha$ . In other words, the following relational expression (6) holds between the diameter D of the revolution locus R, the eccentricity e, and the guide clearance  $\alpha$ .

$$D = 2e = \alpha \quad \dots (6)$$

30 The rattling tolerance B refers to a range in which the annular cage 5 can move in every direction in a state in which the balls 4 are fixed in fixed positions. The



rattling tolerance is shown with lines connecting displaced positions of the center P2 of the annular cage 5 when the annular cage 5 is moved in the respective directions.

5           Because the eccentricity tolerance A of the annular cage 5 is determined by the guide clearance  $\alpha$  and the rattling tolerance B of the annular cage 5 is determined by the pocket clearance  $\beta$ , a circle showing the eccentricity tolerance A of the annular cage 5 becomes  
10           larger than the octagon showing the rattling tolerance B as shown in FIGS. 4A and 4B, if a relationship between the guide clearance  $\alpha$  and the pocket clearance  $\beta$  is set to be  $\alpha > \beta$ . Therefore, if the relationship between the guide clearance  $\alpha$  and the pocket clearance  $\beta$  is set to  
15           be  $\alpha > \beta$ , movement of the annular cage 5 is restricted in a range shown with a hatch pattern. Hatch patterns in cases of FIGS. 4A and 4B are within the rattling tolerance B of the annular cage 5.

20           The annular cage 5 can move an extra distance Bpe in the drawings in the radial direction. Bpe is the maximum value of a difference between the eccentricity tolerance A and the rattling tolerance B. In this case, when the annular cage 5 is displaced in the radial direction as a result of rotation, inner wall faces of  
25           the pockets 8 in the annular cage 5 interfere with the balls 4 and a range of eccentricity of the annular cage 5 is restricted by the balls 4. Therefore, because large force is applied to the balls 4 due to the interference, the balls 4 are liable to advance and lag to generate  
30           a pitch error of the balls 4. The pitch error refers to irregular intervals between the plurality of balls 4 which are to be properly disposed at constant intervals in the circumferential direction.

If the relationship between the guide clearance  $\alpha$  and the pocket clearance  $\beta$  is set to be  $\alpha = \beta$ , as shown in FIG. 4C, a circle showing the eccentricity tolerance A of the annular cage 5 is the largest inscribed circle of the octagon showing the rattling tolerance B. Therefore, movement of the annular cage 5 is restricted in a range shown with a hatch pattern. The hatch pattern in FIG. 4C is within the eccentricity tolerance A of the annular cage 5.

In this case, though there is a fear that the inner wall faces of the pockets 8 slightly interfere with the balls 4 when the annular cage 5 is displaced in the radial direction because of rotation, the range of eccentricity of the annular cage 5 is not restricted by the balls 4. With such slight interference, only small force is applied to the balls 4. Therefore, the balls 4 are less liable to advance and lag and the pitch error of the balls 4 can be suppressed.

If the relationship between the guide clearance  $\alpha$  and the pocket clearance  $\beta$  is set to be  $\alpha < \beta$ , a circle showing the eccentricity tolerance A of the annular cage 5 is smaller than the octagon showing the rattling tolerance B as shown in FIG. 4D. Movement of the annular cage 5 is restricted in a range shown with a hatch pattern. The hatch pattern in FIG. 4D is within the eccentricity tolerance A of the annular cage 5.

In this case, because the inner wall faces of the pockets 8 of the annular cage 5 do not interfere with the balls 4 at all when the annular cage 5 is displaced in the radial direction because of rotation, the range of eccentricity of the annular cage 5 is not restricted by the balls 4. Therefore, the balls 4 do not advance and lag and, as a result, the pitch error of the balls

4 does not generate.

In all the cases of  $\alpha > \beta$ ,  $\alpha = \beta$ , and  $\alpha < \beta$ , the pockets 8 may interfere with the balls 4 when the annular cage 5 is displaced in the circumferential direction.

5 This interference is ignored in the embodiment.

Results of simulations of a maximum amount of displacement of the annular cage 5 in the radial direction when the guide clearance  $\alpha$  is constant and the pocket clearance  $\beta$  is used as a parameter in contrast to the above case will be described.

In these simulations, a diameter of each ball 4 is set at 3/8 in., the number of balls 4 is set at 27, a diameter (P.C.D.) of a circle connecting centers of the respective balls 4 is set at 112.5 mm, and the guide clearance  $\alpha$  is set at 0.3 mm.

A result of the simulations is that, as shown in a graph in FIG. 6, a maximum amount of displacement of the annular cage 5 in the radial direction is 0.15 mm, i.e., the annular cage 5 comes into contact with the inner peripheral face of the outer ring 3 if the relationship between the pocket clearance  $\beta$  and the guide clearance  $\alpha$  is  $\alpha \leq \beta$ , i.e., the pocket clearance  $\beta$  is 0.3 mm or greater while the guide clearance  $\alpha$  is 0.3 mm. This means that the pockets 8 in the annular cage 5 do not interfere with the balls 4.

On the other hand, if  $\alpha > \beta$ , i.e. the pocket clearance  $\beta$  is gradually reduced to be smaller than 0.3 mm while the guide clearance  $\alpha$  is 0.3 mm, the maximum amount of displacement of the annular cage 5 in the radial direction is gradually reduced to be smaller than 0.15 mm and the annular cage 5 does not come in contact with the inner peripheral face of the outer ring 3. This means that the pockets 8 in the annular cage 5 interfere

with the balls 4.

Based on the above-described results, it is effective that the relationship between the guide clearance  $\alpha$  and the pocket clearance  $\beta$  is set to be  $\alpha \leq \beta$ . In other words, the smaller the guide clearance  $\alpha$  than the pocket clearance  $\beta$ , the better. However, the smaller the guide clearance  $\alpha$ , the more difficult processing becomes and the higher processing cost becomes. Therefore, in practice, setting the guide clearance  $\alpha$  at a value equal to or slightly smaller than the pocket clearance  $\beta$  is considered preferable.

As described above, if the relationship  $\alpha \leq \beta$  between the guide clearance  $\alpha$  and the pocket clearance  $\beta$  is specified, the annular cage 5 is guided by the outer ring 3 even if the annular cage 5 rotates in an eccentric manner in high-speed rotation. Especially when the annular cage 5 is displaced in the radial direction, the inner wall faces of the pocket 8 hardly interfere with the balls 4. Therefore, behavior of the annular cage 5 is liable to be stable. Each ball 4 becomes less liable to advance and lag. As a result, rolling operation becomes stable in such a manner that minute slip of the balls 4 becomes less liable to generate. Therefore, phenomena such as generation of vibration in the angular contact ball bearing 1 and increase of a temperature over a prescribed temperature are suppressed to thereby contribute to increase of life of the bearing 1.

When the angular contact ball bearing 1 is used for high-speed rotation, rotational centrifugal force of the annular cage 5 becomes large and the annular cage 5 and the outer ring 3 are liable to generate heat because the annular cage 5 comes in contact with the outer ring 3 which guides the annular cage 5. Therefore, it is more

desirable in practical terms to set the relationship between the guide clearance  $\alpha$  and the pocket clearance  $\beta$  in view of centrifugal expansion and thermal expansion in the annular cage 5 when the bearing 1 is used for high-speed rotation. To put it concretely, the relationship is set at the following relational expression (7) if an expansion amount of the annular cage 5 in the radial direction due to rotational centrifugal force is  $x$  and an expansion amount of the annular cage 5 in the radial direction due to a temperature rise is  $y$ .

$$x+y < \alpha \leq \beta+x \quad \dots (7)$$

It is preferable in practical terms to set the relationship at the following relational expressions (8) and (9) in view of processing errors of the guide clearance  $\alpha$  and the pocket clearance  $\beta$ .

$$\alpha_{\max} \leq \beta_{\min}+x \quad \dots (8)$$

$$\alpha_{\min} > x+y \quad \dots (9)$$

, where  $\alpha_{\max}$  refers to a maximum value of the guide clearance  $\alpha$ ,  $\alpha_{\min}$  refers to a minimum value of the guide clearance  $\alpha$ , and  $\beta_{\min}$  refers to a minimum value of the pocket clearance  $\beta$ .

As described above, it is more effective in terms of practical use to add the expansion amount  $x$  of the annular cage 5 in the radial direction due to the rotational centrifugal force and the expansion amount  $y$  of the annular cage 5 in the radial direction due to the thermal expansion depending on a kind and a shape of base material selected as the annular cage 5.

Although an example in which the annular cage 5 is of a type guided by the outer ring and used frequently for high-speed rotation of a spindle for a machine tool and the like is given in the above embodiment, the annular

cage 5 may be of a type guided by the inner ring as shown in FIG. 7. The inner ring guiding refers to a type of guiding in which the inside surface of the annular cage 5 is disposed close to the outer peripheral face of the inner ring 2 such that the annular cage 5 rotates along the outer peripheral face of the inner ring 2. In FIG. 7, portions corresponding to those in FIG. 1 are provided with the same reference numerals. The angular contact ball bearing 1A shown in FIG. 7 includes an inner ring 2, an outer ring 3, a plurality of balls 4, and an annular cage 5.

A race is formed in an axial intermediate position of an inner peripheral face of the outer ring 3. A sectional shape of the race is a shape corresponding to a part of an arc. A counter bore with a diameter gradually increasing from the race toward an axial end side is formed in axial one end portion on an inner peripheral face of the outer ring 3.

A race is formed in an axial intermediate position of an outer peripheral face of the inner ring 2. A sectional shape of the race is a deep groove shape corresponding to a part of an arc.

A pre-load is applied to the balls 4 such that the balls 4 are brought into contact with the respective races of the inner and outer rings 2 and 3 at predetermined contact angles.

The annular cage 5 is disposed in an annular space between the inner ring 2 and the outer ring 3 where the inner and outer rings 2 and 3 face each other. The outside diameter surface of the annular cage 5 is disposed close to the outer peripheral face of the inner ring 2.

Conventionally, the fewer the balls 4 to be used,

the smaller the number of angles of the polygon of an outside diameter shape of the rattling tolerance is, in general, and behavior of the annular cage 5 tends to be bad. Therefore, it is possible to obtain desirable effects if the invention is applied to the ball bearing in which the number of the balls 4 to be used is small.

Although the present invention applied to the angular contact ball bearing as the ball bearing has been described, the invention can also be applied to other types of the ball bearings. For example, the invention can be applied basically similarly to the embodiment to a deep groove ball bearing having a cage which is guided by the inner or outer ring and has cylindrical pockets.

While there has been described what is at present considered to be preferred embodiments of this invention, it will be understood that various modifications may be made therein, and it is intended to cover in the appended claims all such modifications as fall within the true spirit and scope of this invention.